Ammonia Sensors Based on Suspended Silicon Nanowires

Laurent Pichon, Anne-Claire Salaün, Gertrude Wenga, Régis Rogel, Emmanuel Jacques

▶ **To cite this version:**

Laurent Pichon, Anne-Claire Salaün, Gertrude Wenga, Régis Rogel, Emmanuel Jacques. Ammonia Sensors Based on Suspended Silicon Nanowires. EUROSENSOR 2014, Sep 2014, BRESCIA, Italy. 10.1016/j.proeng.2014.11.329 . hal-01113257

HAL Id: hal-01113257
https://hal.science/hal-01113257

Submitted on 5 Feb 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Ammonia sensors based on suspended silicon nanowires

L. Pichon, A. C. Salaun, G. Wenga, R. Rogel, E. Jacques
Département Microélectronique et Microcapteurs, Institut d'Electronique et de Télécommunications de Rennes (DM2-IETR, UMR 6164), Rennes, FRANCE

Summary (maximum 150 words)
Resistors based on parallel suspended polycrystalline silicon nanowires are fabricated using the classical top down CMOS silicon technologies. Results show potential use of silicon nanowires for charged chemical species (ammonia) detection. Resistors are promising as low-cost manufacturing gas sensors, for very high sensitive ammonia detection over a large concentration range.

Motivation and results
Thanks to their high surface to volume ratio, silicon nanowires (SiNWs) are good candidates as sensitive units for fabrication of high sensitive chemical sensors. SiNWs can be prepared by one of two approaches, "top down" or "bottom up". In a bottom up strategy the individual base elements (atoms, molecules…) of the system are linked together to form larger subsystems, without using high cost lithographic tools. The main drawbacks of these synthesis methods are the difficulty in control of size and positioning of the nanowires. In this case, nanowires need to be selectively collected and manipulated to be assembled in a planar layout. The "top down" approach starts from bulk materials and scales down the patterned areas. In this way, several advanced high cost lithographic tools with nanometer size resolution are needed, and the low throughput capability is unsuitable with mass production.
In this work, polycrystalline silicon nanowires are synthesized following the top down approach, using a classical fabrication method commonly used in microelectronic industry: the sidewall spacer formation technique [1]. Assets of this technological process rest on low cost lithographic tools, classical silicon planar technology compatibility, and the possibility to get numerous parallel nanowires with precise location on the substrate. Because SiNWs act as sensitive units, specific designs are developed to allow large sensing areas. Two types of resistors (fig. 1 and 2) based on grounded or suspended SiNWs are studied as gas (ammonia) sensors. Resistors process fabrication is compatible with a mass production planar layout.
Ammonia molecules adsorbed on the surface of undoped SiNWs act as electron donors (reducing agents) resulting to an increase of the current into the nanowires. The ammonia detection is checked by measuring the relative response of the sensors defined by:

$$S_g=(I-I_g)/I$$

where I and I_g are the current values for devices in vacuum and reactive ambience respectively.
First measurements presented in fig.3 are carried out at room temperature, in a vacuum chamber, under controlled ammonia/nitrogen (NH_3:N_2) mixture varying from 2 ppm to 700 ppm. For each type of sensors, response to ammonia detection follows a linear behaviour (fig. 3). Results highlight that S_g is higher for suspended polycrystalline SiNWs based devices, related to a high surface to volume ratio of the sensitive units. In addition, relative sensitivity, $\Delta S_g/\Delta[NH_3]$, of such sensors is linearly dependent on the surface to volume ratio of the sensitive units (fig. 4).
These results show potential use of these SiNWs based sensors for charged chemical species (ammonia) detection in a fully compatible silicon CMOS technology.
The effects of the shape of sensitive silicon nano-objects (nanowires, nanoribbons…), silicon crystal quality, and the low detection limit of the sensors will also be discussed.

References
[1] F. Demami, L. Pichon, R. Rogel, A. C. Salaun, *Fabrication of polycrystalline silicon nanowires using conventional UV lithography*, Materials Science and Engineering, 6 (2009) 012014.

Word count: 494
Corresponding author: L. Pichon, D2M-IETR, campus de beaulieu, 35042 Rennes, France, phone: +332 23 23 56 65, fax: +332 23 23 56 57, email : laurent.pichon@univ-rennes1.fr

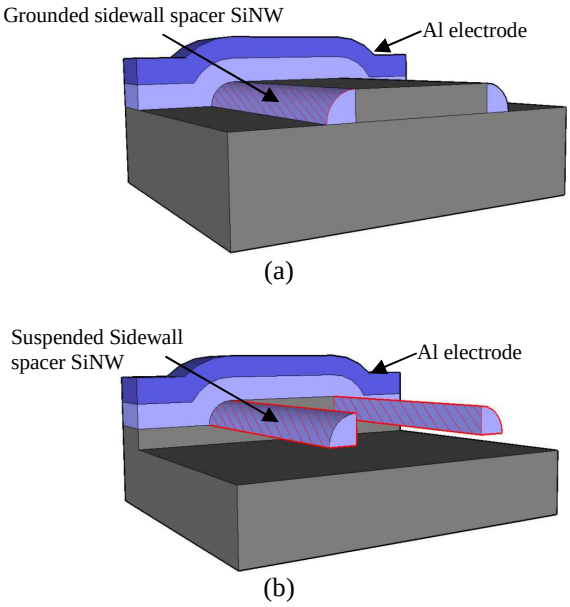

Fig. 1: Schematic view of grounded (a) and suspended (b) sidewall spacer polycrystalline SiNWs based resistors

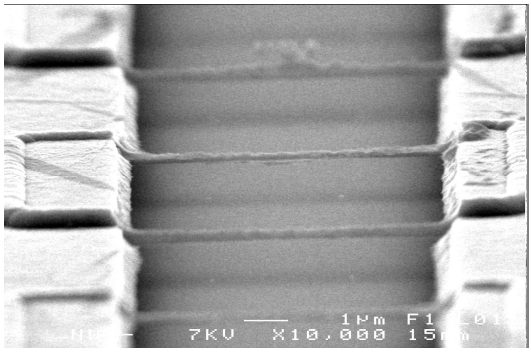

Fig. 2: SEM image of suspended silicon nanowires

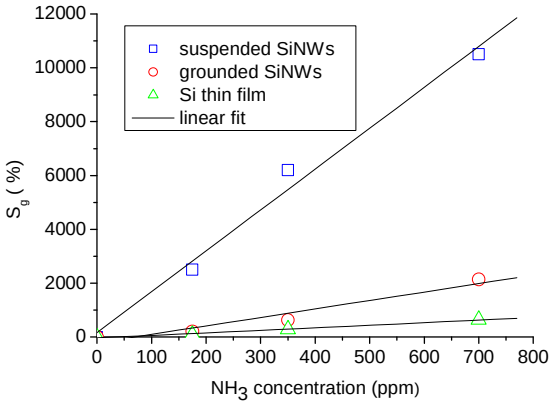

Fig. 3: Relative response of de sensors vs the ammonia concentration for suspended, grounded SiNWs and thin film silicon based resistors.

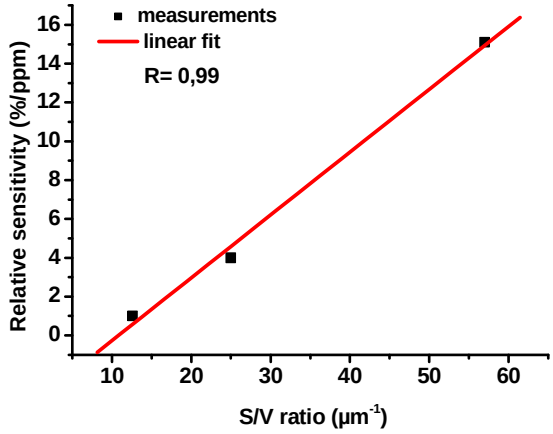

Fig. 4: Relative sensitivity of ammonia sensors vs the surface/volume ratio.